

The financial burden of surgical and endovascular treatment of diabetic foot wounds

Maximilian O. Joret,^a Anastasia Dean, MBBS,^b Colin Cao, PGDipPH,^c Joanna Stewart, MSc,^d and Venu Bhamidipaty, FRACS,^b *Auckland, New Zealand*

Objective: The cost of treating diabetes-related disease in New Zealand is increasing and is expected to reach New Zealand dollars (NZD) 1.8 billion in 2021. The financial burden attached to the treatment of diabetic foot wounds is difficult to quantify and reported costs of treatment vary greatly in the literature. As of yet, no study has captured the true total cost of treating a diabetic foot wound. In this study, we investigate the total minimum cost of treating a diabetic foot ulcer at a tertiary institution.

Methods: A retrospective audit of hospital and interhospital records was performed to identify adult patients with diabetes who were treated operatively for a diabetic foot wound by the department of vascular surgery at Auckland Hospital between January 2009 and June 2014. Costs from the patients' admissions and outpatient clinics from their first meeting to the achievement of a final outcome were tallied to calculate the total cost of healing the wound. The hospital's expenses were calculated using a fully absorbed activity-based costing methodology and correlated with a variety of demographic and clinical factors extracted from patients' electronic records using a general linear mixed model.

Results: We identified 225 patients accounting for 265 wound episodes, 700 inpatient admissions, 815 outpatient consultations, 367 surgical procedures, and 248 endovascular procedures. The total minimum cost to the Auckland city hospital was NZD 10,217,115 (NZD 9,886,963 inpatient costs; NZD 330,152 outpatient costs). The median cost per wound episode was NZD 29,537 (NZD 28,491 inpatient costs; NZD 834 outpatient cost). Wound healing was achieved in 70% of wound episodes (average length of healing, 9 months); 19% of wounds had not healed before the patient's death. Of every 3.5 wound episodes, one required a major amputation. Wound treatment modality, particularly surgical management, was the strongest predictor of high resource utilization. Wounds treated with endovascular intervention and no surgical intervention cost less. Surgical management (indiscriminate of type) was associated with faster wound healing than wounds managed endovascularly (median duration, 140 vs 224 days). Clinical risk factors including smoking, ischemic heart disease, hypercholesterolemia, hypertension, and chronic kidney disease did not affect treatment cost significantly.

Conclusions: We estimate the minimum median cost incurred by our department of vascular surgery in treating a diabetic foot wound to be NZD 30,000 and identify wound treatment modality to be a significant determinant of cost. While readily acknowledging our study's inherent limitations, we believe it provides a real-world representation of the minimum total cost involved in treating diabetic foot lesions in a tertiary center. Given the increasing rate of diabetes, we believe this high cost reinforces the need for the establishment of a multidisciplinary diabetic foot team in our region. (*J Vasc Surg* 2016;64:648-55.)

According to World Bank data, worldwide medical expenditures per capita have doubled in the last 10 years. In New Zealand, health care expenditure has increased from 7 million in 1925 to 19.9 billion in 2010 with an average growth rate of 5.1% per annum.¹ Having more than doubled as a percentage of gross domestic product over the past 60 years, it is expected to account for 10.7% of

total gross domestic product in 2050.² A considerable part of this increasing cost is attributable to the increased incidence of diabetes and diabetes-related complications. In the United States, the cost of diabetes has risen from USD 174 billion in 2007 to USD 245 billion in 2012,³ with the cost per individual patient doubling in the past two decades.⁴ Meanwhile, in New Zealand, the cost of type 2 diabetes has increased from New Zealand dollars (NZD) 247 million in 2001 to NZD 600 million in 2008, and is expected to reach NZD 1.3 billion in 2016 and NZD 1.8 billion in 2021.⁵

In 2001, diabetic foot disease cost USD 10.9 billion and GBP 252 million in health care expenditures to the United States and UK respectively, representing approximately 24% of the health care expenditures attributable to diabetes for that year.⁶ The estimated cost of healing a diabetic foot ulcer in the literature ranges from USD 993 to USD 17,519 for primary healing, and USD 16,488 to USD 66,215 for healing by amputation.⁶ Australian figures estimate that diabetes-related foot ulcers and amputations cost approximately AUD 14,691 and AUD 23,555, respectively, in the initial year, but these figures only

From the School of Medicine, Faculty of Medical and Health Sciences,^a and the Department of Epidemiology & Biostatistics, School of Population Health, Faculty of Medical and Health Sciences,^d The University of Auckland; and the Department of Vascular Surgery, Auckland Hospital,^b and Department of Business Intelligence,^c ADHB.

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Correspondence: Venu Bhamidipaty, Department of Vascular Surgery, Auckland Hospital, Park Rd, 1010 Auckland, New Zealand (e-mail: venubham@gmail.com).

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include direct costs to the third-party payer (government or private insurance agency) and exclude opportunity costs and costs to other parties.⁷ Costs also seem to extend well beyond the initial “ulcer” presentation: in a retrospective nested case-control study, the relative cost of care for diabetic patients with lower extremity ulceration was 1.5 to 2.4 times higher than that of diabetic patients without an ulcer in the year before diagnosis, and 5.4 times higher in the year after the ulcer episode due to more hospital admissions, outpatient clinics, and presentations to the emergency department.⁸ Many studies calculating the costs of diabetic foot ulceration identify hospital admissions and duration of stay as significant factors contributing to overall costs.⁹⁻¹¹

With predictions that 10% of the population of New Zealand will be affected by type 2 diabetes by 2028,¹² the development and implementation of cost effective treatment and patient management systems is key to achieving long-term sustainable health care. In this study, we calculate the minimum total cost of healing a diabetic foot ulcer incurred by a vascular surgery unit at the largest tertiary hospital in New Zealand.

METHODS

Ethics approval. Institutional ethics approval for this study was granted by the Low Risk Ethics Committee at our regional hospital network and the need for individual patient consent waived owing to the unidentifiable pooled nature of the data presented in this study.

Primary end point.

- Calculate the average cost incurred by the department of vascular surgery at Auckland District Health Board for the treatment of diabetic foot wounds.

Secondary end points.

- Characterize the duration, cost, and success of healing diabetic foot wounds in the current treatment setting of the department of vascular surgery at Auckland city hospital.
- Identify patient factors, comorbidities, and treatments and their effects on the cost, duration, and success of the treatment of a typical diabetic foot wound.

Patient identification and selection. To identify patients with diabetes who were treated for a diabetic foot ulcer in our vascular surgery unit, we reviewed hospital operating lists, a regional surgical audit, and internal interventional radiology records from January 2009 to July 2014. Using coding from the operating room, we identified 201 diabetic patients who had undergone lower limb revascularization surgery (bypass, endarterectomy, thrombectomy), major and minor amputations, and surgical debridements or local repairs (including split skin graft) of a wound by the vascular surgery unit. A regional vascular surgery database, The Australian & New Zealand Society for Vascular Surgery’s Australasian Vascular Audit, of which

our hospital is a participant, was then reviewed for patients who had undergone the same procedures but had been missed on the hospital operative lists. This identified a further 104 patients with diabetes.

To identify patients who had undergone endovascular interventions, a report was generated of all digital subtraction angiography in the aortoiliac and lower limb regions performed during the study dates. Imaging requests and radiology reports were reviewed and studies included if there was a reference to foot ulceration or tissue loss. If clinical information was unclear, the patient’s electronic records were cross-checked to see if the study was related to active foot ulceration. Of 1885 procedures that were performed, 584 studies were related to foot tissue loss/ulceration. From this, 98 patients with diabetes were identified who had not been captured in the operative databases.

Wound episode identification and selection. Electronic records of the 403 selected patients were reviewed, including admission notes, clinic letters, referral letters, operative notes, and interventional radiology reports. The first reference to a wound was recorded as the start of the “wound episode”; the first reference to healing (or achievement of another final outcome) was the completion point. The hospital financial code for every relevant inpatient admission and outpatient clinic during this period was recorded. Admissions and clinics were not considered relevant if they were not primarily for the treatment or management of that wound/ulcer. In the event that a patient developed a subsequent wound during the study period, a separate wound episode was recorded. Wound episodes were excluded if the wound was present prior to January 2009 or if a final outcome was not achieved by July 2014. Furthermore, wound episode of patients who received care for the ulcer from another departments or hospitals were also excluded, because the incurred cost would be difficult to ascertain accurately. Finally, a few wound episodes were excluded because of insufficient clinical information in patient electronic records. A pictorial representation of our study’s patient recruitment architecture is provided in Fig 1.

Wound episode-related data extraction. Along with patient demographics and risk factors, information was collated on the intervention performed, both surgical and radiologic. The final outcome of each wound episode was classed into one of four categories: “healed”, where the patient’s wound had definitely healed; “died”, where the patient’s death had occurred before wound healing could be achieved; “failed”, where the patient had been discharged from services with no further intervention planned in the absence of healing; and “lost” where the patient was lost to follow-up.

Cost calculation. To calculate the cost of each wound episode, the list of the financial codes for the relevant inpatient admissions and outpatient clinics was provided to the financial department. Costs were calculated at an event level and total resource utilization was identified by episodes of care. Patient activity and patient demographic

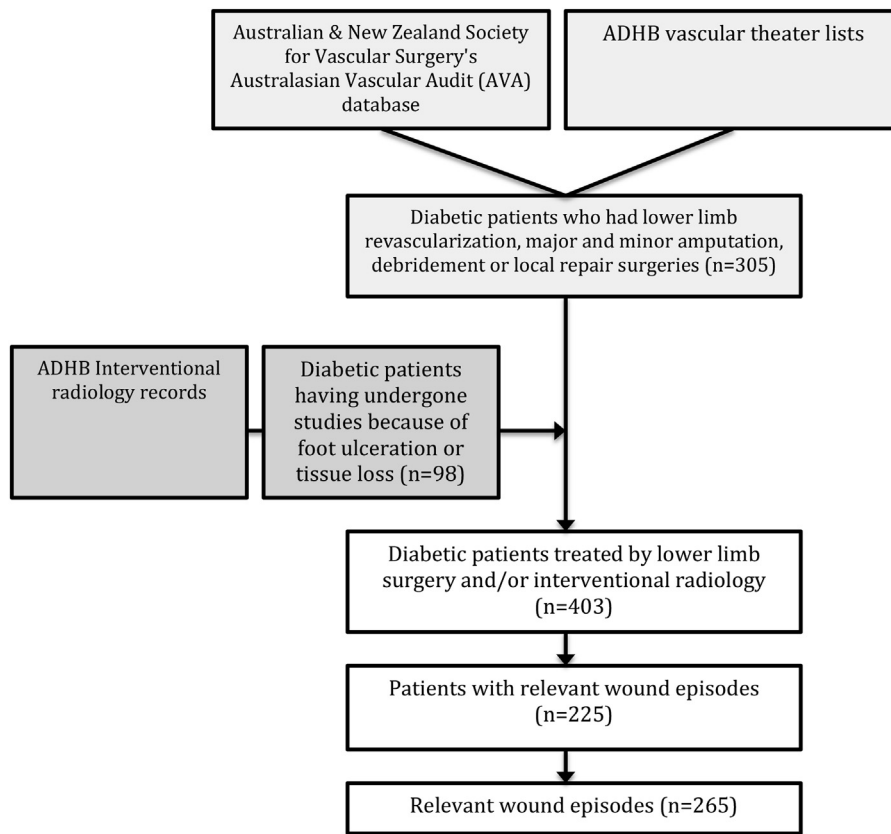


Fig 1. Architecture of study patient recruitment. ADHB, Auckland City Hospital.

data captured in the clinical systems was entered into Power Performance Manager as well as financial data from the general ledger. The expenditure data was allocated to particular episodes of care based on resource utilization, resulting in a total individual estimated cost for each patient wound episode. The methodology used was fully absorbed activity based costing and all costs in this study are stated in NZD. The average exchange rate from NZD to USD over the length of the study was 0.77.

Statistical analysis. To investigate the association of method of treatment with cost, accounting for other variables that could also be associated with cost, a general linear mixed model was used. Because costs had a skewed distribution, with a small number of very high values, the logarithmic value of cost was used as the outcome. Explanatory variables included treatment, age in years, gender, ethnicity, smoking status, and risk factor profile (including diagnoses of ischemic heart disease, hypercholesterolemia, chronic kidney disease, and hypertension). Person was included as a random effect to account for the within person correlation for patients with more than one wound. Least square means of the cost for the different treatment modalities, with 95% confidence intervals (CIs) were formed and back transformed to the NZD original scale. Preplanned contrasts comparing specific types of treatment of interest were also investigated.

RESULTS

Patient characterization. A total of 225 patients were identified, 146 of which were men (64.9%) with a mean age of 69.8 ± 10.3 years and 78 (34.7%) were women with a mean age of 69.2 ± 13.7 years. Gender information was unavailable for one patient. The largest ethnic group was European ($n = 136$) followed by Maori ($n = 34$), Pacific Islander ($n = 30$), Indian ($n = 14$), Asian ($n = 7$), African ($n = 2$), and unspecified ($n = 2$). Twenty-one patients (9.3%) were current smokers at the time of their presentation; 83 (36.9%) were ex-smokers and 121 (53.8%) were nonsmokers. Smoking status breakdown by gender is available in Table I.

In terms of comorbidities, 190 of the patients (84.4%) had a documented diagnosis of hypertension, 105 (46.7%) hypercholesterolemia, 100 (44.4%) ischemic heart disease, and 90 (40.0%) chronic kidney disease. Further risk factor distribution is summarized in Table II.

The 225 patients accounted for 265 wound episodes with 193 having had only 1 wound episode, 27 having had 2, 3 having had 3, and 2 having had 5 separate wound episodes.

Wound episode characterization. The 265 wound episodes accounted for 700 inpatient admissions and 815 outpatient consultations. The average number of inpatient

Table I. Smoking status distribution by gender

Cohort	All, %	Male, %	Female, %
Smoker	09.3 (21/225)	09.6 (14/146)	09.0 (7/78)
Ex-smoker	36.9 (83/225)	45.2 (66/146)	21.8 (17/78)
Nonsmoker	53.8 (121/225)	45.2 (66/146)	69.2 (54/78)

Table II. Risk factor distribution across all patients stratified by gender

Cohort	All, %	Male, %	Female, %
All	225	146	78
HT	84.4 (190/225)	83.6 (122/146)	84.6 (66/78)
HC	46.7 (105/225)	45.2 (66/146)	48.7 (38/78)
IHD	44.4 (100/225)	43.8 (64/146)	44.9 (35/78)
CKD	40.0 (90/225)	41.1 (60/146)	38.5 (30/78)

CKD, Chronic kidney disease; HC, hypercholesterolemia; HT, hypertension; IHD, ischemic heart disease.

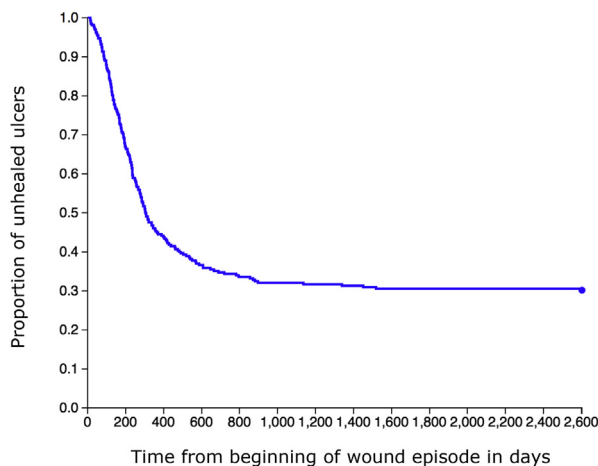


Fig 2. A Kaplan-Meier curve correlating the proportion of unhealed ulcers against time from the beginning of wound episodes.

admission was 2.64 per wound episode with an average duration of admission of 39 days. The average number of outpatient clinics was 3.08 per wound episode.

Patients underwent a total of 367 operations including 157 amputations (73 major and 84 minor), 122 debridements, 22 local wound repairs (split skin graft), and 66 open revascularization procedures including arterial bypass, endarterectomy and thromboembolectomy. There were 248 interventional radiology procedures performed. Ninety-nine (37%) wounds were treated by surgical intervention only, 72 (27%) by percutaneous endovascular intervention alone, and 94 (35%) by a combination of surgery and endovascular procedures. Seventy-one (27%) wounds required a major amputation (above- or below-knee) as part of their treatment.

Table III. Results of the general linear mixed model looking at variables related to cost of wound treatment

Effect	Num DF	Den DF	F value	Pr > F
TM	4	245	17.96	<0.0001
Age	1	225	1.40	0.24
Ethnicity	3	229	0.66	0.58
Gender	1	223	1.66	0.20
IHD	1	209	0.07	0.79
HC	1	214	2.62	0.11
HT	1	217	0.03	0.86
Smoker	1	215	2.82	0.09
CKD	1	213	1.96	0.16

CKD, Chronic kidney disease; DF, degrees of freedom; HC, hypercholesterolemia; HT, hypertension; IHD, ischemic heart disease; TM, treatment modality.

Table IV. Geometric least square mean (LSM) of costs of different treatment modalities from the generalized mixed model analysis with 95% confidence intervals

Procedure	Back transformed LSM	Lower 95% CL	Upper 95% CL
SURG AMP	24,294.37	17,572.67	33,587.19
SURG IR AMP	53,766.18	41,200.27	70,164.66
SURG IR NO AMP	42,595.33	32,389.84	56,010.81
SURG ONLY	22,838.43	17,845.38	29,228.51
IR ONLY	17,606.09	13,717.12	22,599.88

CL, Confidence limit; IR ONLY, treatment included interventional radiology procedures only; SURG AMP, treatment included surgical procedures only including major amputation; SURG IR AMP, treatment included a combination of surgical and interventional radiology procedures including major amputation; SURG IR NO AMP, treatment included a combination of surgical and interventional radiology procedures but no major amputation; SURG ONLY, treatment included surgical procedures only.

Outcome and length of wound healing. One hundred eighty-five wound episodes (69.8%) ended with the achievement of a permanently healed wound, 2 (0.7%) with a discharge from care in the absence of wound healing, and 51 (19.3%) with the death of the patient. Twenty-seven patients (10.2%) did not attend scheduled follow-up and were lost to the community. We observed that healing rates varied between treatment modality groups. The best healing rate (75.0%) and lowest mortality rate (13.9%) was seen in patients with wounds exclusively treated by endovascular procedures. Wounds exclusively treated surgically achieved a healing rate of 69.7% and a mortality rate of 18.2%. The worst outcomes were found in wounds that required major amputations (healing rate of 53.5% and mortality of 32.4%). The median duration of healing for wounds that were solely treated with surgery, however, was less (140 days) than that of wounds solely treated with endovascular intervention (224 days). The median duration of healing a diabetic foot ulcer across all treatment modalities was 176 days. A Kaplan-Meier curve correlating the proportion of unhealed ulcers against time is provided in Fig 2.

Table V. Study results on cost, length, and outcome of wound episodes stratified by patient characteristics

<i>Description</i>	<i>No.</i>	<i>%</i>	<i>Median cost per wound episode, \$</i>	<i>Median length of WE</i>	<i>Healed</i>	<i>%</i>	<i>Died</i>	<i>%</i>	<i>Failed</i>	<i>%</i>	<i>Lost</i>	<i>%</i>
All	265	100.00	29,537	176	185	69.81	51	19.25	2	0.75	27	10.19
Ethnicity												
European/others	179	67.55	28,753	182	127	70.95	35	19.55	2	1.12	15	8.38
Maori	38	14.34	30,131	140	23	60.53	10	26.32	0	0.00	5	13.16
Pacific Islanders	33	12.45	36,186	175	24	72.73	3	9.09	0	0.00	6	18.18
Indians	15	5.66	39,852	293	11	73.33	3	20.00	0	0.00	1	6.67
Gender												
Male	174	65.66	28,889	183	124	71.26	31	17.82	1	0.57	18	10.34
Female	90	33.96	33,369	168	61	67.78	20	22.22	1	1.11	8	8.89
Risk factors												
Smokers (including ex)	128	48.30	29,661	185	97	75.78	19	14.84	0	0.00	12	9.38
Ischemic heart disease	124	46.79	30,796	178	86	69.35	28	22.58	2	1.61	8	6.45
Hypercholesterolemia	124	46.79	27,451	171	88	70.97	22	17.74	2	1.61	12	9.68
Hypertension	225	84.91	29,360	179	159	70.67	43	19.11	2	0.89	21	9.33
Chronic kidney disease	106	40.00	30,292	157	68	64.15	29	27.36	2	1.89	7	6.60
Treatment												
Surgical only	99	37.36	22,159	140	69	69.70	18	18.18	0	0.00	12	12.12
Major amputation	71	26.79	42,774	116	38	53.52	23	32.39	0	0.00	10	14.08
Endovascular only	72	27.17	18,461	224	54	75.00	10	13.89	2	2.78	6	8.33
Combination	94	35.47	52,110	180	62	65.96	23	24.47	0	0.00	9	9.57
Outcome												
Healed	185	69.81	28,753	216	185	100.00	0	0.00	0	0.00	0	0.00
Died	51	19.25	35,639	83	0	0.00	51	100.00	0	0.00	0	0.00
Failed	2	0.75	29,655	299	0	0.00	0	0.00	2	100.00	0	0.00
Lost	27	10.19	33,336	115	0	0.00	0	0.00	0	0.00	27	100.00

Cost of wound treatment. Over the study period, Auckland city hospital spent at total of NZD 10,217,115 (NZD 9,886,963 in inpatient costs and NZD 330,152 in outpatient costs) on the treatment of the 265 wound episodes. The median cost per wound episode was NZD 29,537, of which 96% was attributable to inpatient cost. The median cost for treating a wound in a male patient was NZD 28,889 compared with NZD 33,369 for female patients.

The median cost per wound episode for the wounds that were treated solely by surgical intervention was NZD 22,159. For those treated with endovascular intervention only, the median cost was NZD 18,461 and for the remaining wounds which were treated by a combination of surgery and endovascular intervention the median cost of treatment was NZD 52,110.

In our general linear mixed model, differences in cost attributable to variations in treatment modalities were statistically significant ($P < .0001$; Table III).

More specifically, the cost ratio of wounds treated by endovascular intervention only compared with those treated by surgery only was 0.52 (95% CI, 0.43-0.66; $P < .0001$). That of wounds treated by surgery only compared with wounds treated by a combination of surgical and endovascular techniques was 0.49 (95% CI, 0.39-0.62; $P < .0001$).

A statistically significant difference could not be demonstrated in the subgroup of wounds treated surgically between those which engendered a major amputation and those who did not despite the cost ratio indicating that

wounds requiring a major amputation cost 1.16 times the cost of those who did not (95% CI, 0.91-1.48; $P = .24$).

Major amputations did, however, seem to be a statistically significant determinant of cost when comparing wounds treated by major amputations to all others with a Wilcoxon two-sample test (two-sided $Pr Z < .0001$). The median cost per wound episode that included a major amputation was NZD 42,774 compared with NZD 27,385 for wounds not requiring this operation.

No further statistically significant associations with cost could be demonstrated with any of the other variables included in the model (Table III).

Additional information regarding geometric least square means of costs of different treatment modalities and median cost and outcome distributions stratified by wound episode characteristic is available in Tables IV and V.

DISCUSSION

Wound healing was achieved in 70% of patients and took an average of 9 months at a minimum median cost of almost NZD 30,000 per wound. On average, each ulcer episode required 2.63 inpatient admissions, with a total duration of almost 40 inpatient days. Noticeably, in the 265 wound episodes, 73 major amputations were performed, which averages out to one major amputation in the management of every 3.5 wounds. This statistic was much higher than we had expected, as was the total cost incurred per wound episode.

Table VI. Collation of key figures assessing ulcer cost as cited in the literature (modified with permission from Driver et al⁸).

<i>First author, year</i>	<i>Study type</i>	<i>Study population</i>	<i>Results</i>	<i>Notes</i>
Holzer, 1998 ²¹	Retrospective analysis of private insurance claims	3013 subjects Study period 1991-1992 Age: 18-64 years 3524 ulcer episodes	Average ulcer episode cost: \$4595 1. Primary healing \$1929 2. Healing by amputation: 44,790 Grade 1 or 2 ulcer cost \$1929 Grade 3 ulcers cost: \$3980 Grade 4 or 5 ulcers cost: \$15,792	Severity grading according to Wagner classification as 1 or 2; 3; 4 or 5
Harrington, 2000 ¹¹	Retrospective analysis of Medicare claims	>400,000 Medicare beneficiaries with DFUs Study period: 1995-1996	Aggregate disease attributable cost: \$1.45 billion Average ulcer related cost / year: \$3609 Medicare spending among ulcer patients/y: \$15,309 All Medicare spending among all Medicare patients/y: \$5266	Excess cost for ulcer patients: 73.7% inpatient 10.9% outpatient 11.4% home health 4.0% SNF/Hospice
Ramsey, 1999 ²²	Retrospective case control study in HMO	8905 subjects Study period: 1992-1995 Age > 18 years 541 foot ulcers	Average cost of ulcer episode over 1 year: \$26,490 Total attributable cost of DFU: \$27,987	Ulcer patient had more inpatient days and more emergency department visits over the study period
Apelqvist 1994 ⁹	Prospective study	314 subjects with DFU Subjects followed-up through their ulcer episode	Average ulcer episode cost: 1. Primary healing: \$6664 2. Healing by amputation: \$44,790	Cost of ulcer patients: 61% inpatient 39% outpatient
Stockl, 2004 ²³	Retrospective claims data analysis	2253 subjects Study period: 2000-2001	Average ulcer episode cost: \$13,179 Grade 1 ulcers: \$1892 Grade 2 ulcers: \$4345 Grade 3 ulcers: \$12,255 Grade 4 or 5 ulcers: \$27,721	Severity grading according to Wagner classification as 1; 2; 3; 4 or 5 77% inpatient cost
Benotmane, 2001 ¹⁰	Retrospective analysis	163 Algerian subjects Study period 1989-1993	Mean ulcer episode cost: \$5610 Grade 1 or 2 ulcers: \$3326 Grade 3 ulcers: \$5712 Grade 4 or 5 ulcers: \$7399	Severity grading according to Wagner classification as 1 or 2; 3; 4 or 5 80% of cost attributable to inpatient stay
Tennvall, 2000 ²⁴	Retrospective analysis	220 subjects with deep foot infections Study period: 1986-1995	Cost of primary healing: \$17,801 Cost of healing by minor amputation: \$34,031 Cost of healing by major amputation: \$30,693	Most important cost driving factor were wound healing duration and repeat surgeries
Hicks, 2014 ²⁵	Retrospective analysis of the nationwide inpatient sample (2005-2010)	336,641 subjects with a primary diagnosis of diabetic foot ulceration	The annual cumulative cost for inpatient treatment of DFUs increased: 2005: \$578,364,261 2010: \$790,017,704 The mean adjusted cost per patient hospitalization increased: 2005: \$11,483 2010: \$13,258	Concluded that cost of DFU increased over time despite stable hospital length of stay and proportion of emergency admission.
Hicks, 2016 ²⁶	Retrospective analysis of the nationwide inpatient sample (2005-2006)	962,496 foot ulcer patients	The overall mean adjusted cost for diabetic foot ulcers was \$9,397 per admission. Total cost for the treatment of 883,465 patients was \$8.3 billion. Diabetic patients with infection cost \$11,290 per admission.	The majority of cost is related to the treatment of infected foot ulcers.

DFU, Diabetic foot ulcer; HMO, health maintenance organization; SNF, skilled nurse facility; WE, wound episode.

Cost varied greatly according to wound treatment modality. The cost ratios for wounds treated endovascularly vs those treated surgically and for those treated surgically vs those treated by a combination of surgery and endovascular intervention were 0.52 and 0.49, respectively.

Despite a cost ratio of 1.16 and being described by other authors as strong a strong driver of cost,⁸ major amputations were, in themselves, not a determinant of high cost in our general linear mixed model when comparing wounds treated by such operations with wounds treated by other surgeries. We stipulate that this result can, in part, be explained by our small sample size and by the fact that rehabilitation costs were not included in this study because they are, in the health system in New Zealand, not incumbent to the department of vascular surgery.

There is a great variance in costs for treating a diabetic foot ulcer in the literature. Differences in health care systems, in availability of technology and personnel, in public and private funding arrangements, in data management systems, and in the aggressiveness with which diabetic foot wounds are managed all undoubtedly affect the costs involved.¹³ It is therefore, not surprising, that no study has yet managed to capture the true total cost of treating a diabetic foot wound including inpatient and outpatient costs as well as costs of consumables (eg, dressings and antibiotics), rehabilitation, and indirect costs such as loss of labor/income or step up in community care needed, including placement in care facilities.

We readily acknowledge that our study has its own inherent limitations, specifically and not limited to, the retrospective nature of the study, the fact that patients who were managed conservatively (no surgical or endovascular procedure) were not captured, and that we have not included some outpatient costs, such as community nursing, general practice, or podiatry clinics. Furthermore, we did not include the costs of rehabilitation. We chose to exclude these costs because we could not accurately denude those costs related specifically to the treatment of the ulcer from those related to other concurrent medical comorbidities. Finally, given the lack of information on wound characteristics in our electronic records, we could not perform a meaningful analysis based on the wound severity (eg, Wagner or Texas wound classification).

This study, however, is the first to evidence the significant link between the choice of endovascular or surgical treatment modalities and overall wound treatment cost. Additionally, it is one of the first to estimate the real minimum total costs to a busy vascular unit in the treatment of diabetic foot wounds and highlights the huge economic burden placed on our health care system by this pathology. The ever-increasing costs of managing this difficult group of patients should prompt us to explore avenues for improving our regional health care delivery system, such as the adoption of a multidisciplinary treatment approach, which has been shown to reduce dramatically the incidence of lower extremity amputations, hospital admissions and emergency department use in patients with diabetic foot disease.

Driver et al⁸ documented that >80% of diabetic amputations are preceded by an ulcer, the presence of which increases the total cost of care more than five times compared with the year prior to ulceration, with increased costs seen for ≤ 2 to 3 years. The authors also calculated that management which included a major amputation for healing of a diabetic foot ulcer was more than seven times more expensive than in cases of primary healing; the majority of the costs involved were owing to inpatient hospital admissions, which is consistent with our results and the literature.⁹⁻¹¹

Driver's study group saw an 82% reduction in major amputations during a 4-year period after a multidisciplinary team was established in their institution. Improved outcomes were also reported by Zayed et al,¹⁴ who attributed 96% limb salvage rates to reducing time between referrals and the revascularization procedures, primarily by using a multidisciplinary approach and developing an integrated care pathway.

As previously stated, a nonnegligible variation exists amongst reported diabetic foot ulcer related costs. Table VI collates key figures assessing ulcer cost as cited in the literature.

There is a paucity of studies in the Australasian literature reporting the costs of diabetic foot disease or the rate of lower limb amputations.¹⁵ Amputation rates and duration of inpatient stay are two easily measurable indices that will help us to understand and improve the quality of health care delivery in this high-risk population. The 'toe-and-flow' model of care proposed by Rogers et al¹⁶ has been shown to improve outcomes significantly by implementing a multidisciplinary approach to managing diabetic foot ulcers. This method has been supported by several other studies,¹⁷⁻²⁰ which have also shown economic and health care benefits after the establishment of multidisciplinary diabetic foot units.

CONCLUSIONS

The true total financial burden posed by a diabetic foot wound is notoriously difficult to accurately capture. Our study, despite its limitations, has demonstrated the minimum average costs incurred by a vascular department in the treatment of a diabetic foot wound and identified wound treatment modality as a major significant determinant of cost. The economic burden evidenced by this study is a lot greater than we had anticipated and further reinforces the need for the establishment of a multidisciplinary diabetic foot team in our region.

AUTHOR CONTRIBUTIONS

Conception and design: MJ, AD, VB
Analysis and interpretation: MJ, AD, CC, JS, VB
Data collection: MJ, AD, CC
Writing the article: MJ, AD, CC, JS, VB
Critical revision of the article: MJ, AD, JS, VB
Final approval of the article: MJ, AD, CC, JS, VB
Statistical analysis: MJ, JS
Obtained funding: Not applicable
Overall responsibility: VB

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